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A Low-Volume Mist Sprayer for Applying Insecticide Concentrates from Ground Equipment[1]

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INTRODUCTION

Use of ultra low-volume applications of technical materials from aircraft to control insects[2,3,4,5,6,7] indicated a need to develop equipment for making such applications from the ground. Because much of the cotton produced in the Southeast is grown in small fields unsuitable for application of low-volume materials from the air, equipment was needed that would disperse low-volume materials from the ground to protect the cotton from insects.

1/ In cooperation with the South Carolina Agricultural Experiment Station.

2/ Messenger, K. Low-volume aerial spraying will be boon to applicators. Agr. Chem. 18(12): 63-64, 66. 1963.

3/ Messenger, K. Low-volume aerial spraying. Agr. Chem. 19(9): 61-62. 1964.

4/ Skoog, F. E., Cowan, F. T., and Messenger, K. Ultra low-volume aerial spraying of dieldrin and malathion for rangeland grasshopper control. J. Econ. Entomol. 58: 559-65. 1965.

5/ Burgess, E. D. Control of the boll weevil with technical malathion applied by aircraft. J. Econ. Entomol. 58: 414-15. 1965.

6/ Ruppel, R. F., and Wilson, M. C. Aerial application of insecticides to control spring infestations of the cereal leaf beetle on small grains. J. Econ. Entomol. 57: 899-903. 1964.

7/ Wilson, M. C., Ruppel, R. F., and Treece, R. F. Low volume concentrate sprays applied by aircraft for control of the cereal leaf beetle. J. Econ. Entomol. 58: 11-14. 1965.

To meet this need, in 1965 a low-volume sprayer was developed and field tested for the control of certain cotton pests at Florence, S.C. It applies low per-acre volumes of materials having different specific gravities and widely differing viscosities that cannot be applied with conventional ground equipment. Some of the advantages of this sprayer as opposed to conventional sprayers operated from the ground are: (1) The addition of water (if any at all is needed) to the formulation is not required in large quantities; (2) number of rows sprayed per swath is greater; (3) application can be accomplished at a greater speed; (4) formulations are less expensive; (5) mixing of spray is eliminated; (6) fewer nozzles are needed; (7) high-pressure pumps to dispense the liquid are not necessary because air pressure is used to force the spray materials to the nozzles; and (8) the sprayer is more easily turned at the end of the rows because the long spray boom has been eliminated.

EQUIPMENT

The sprayer uses a Potts Model No. P-48[8] mist blower having three mist-blower outlets, with the unit mounted on the rear of a self-propelled, 6-foot, high-clearance Barrentine[8] sprayer chassis with each of the mist blower outlets equipped with one Mini-Spin[8] nozzle (Buffalo Turbine Co.) (fig. 1).

The sprayer pressure unit consists of a 2.5-gallon paint pressure tank (Sears, Roebuck and Co., Cat. No. 30G16101K). This tank has a pressure regulator and a liquid-flow control valve. The unit has a small, portable air compressor driven by a gasoline engine (Sears, Roebuck and Co., Cat. No. 283-153301), plus brass pipe, pipe fittings, and plastic tubing (fig. 2).

The mist blower is attached to two pieces of 3-inch angle iron (fig. 3) which are welded to the sprayer frame so that air outlets are 8 feet from the ground. The airblast is directed at an angle of about 15° below the horizontal so that the lower portion of the spray pattern hits the plant foliage about 22 feet from the rear of the machine and the upper portion about 40 feet.

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[8] Mention of a proprietary product in this publication does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval by the Department to the exclusion of other products that may also be suitable.

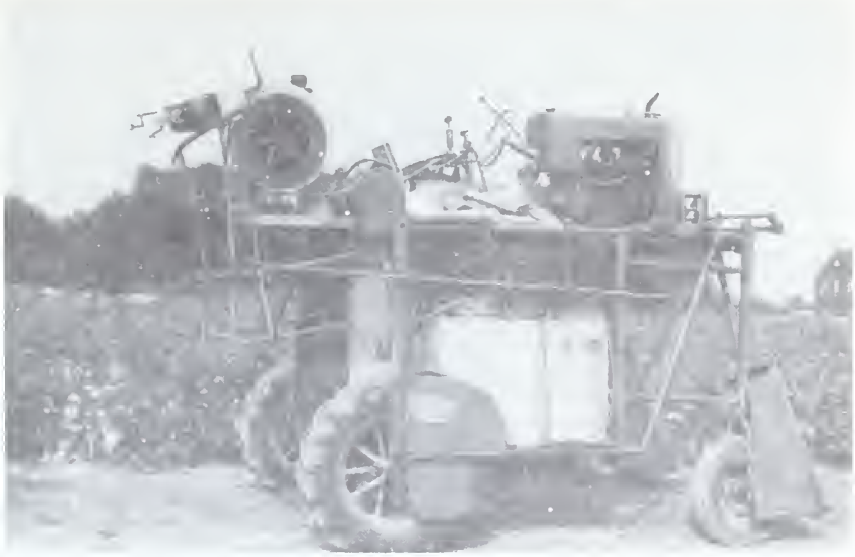

Figure 1.--Low-volume mist sprayer mounted on self-propelled high-clearance sprayer chassis.

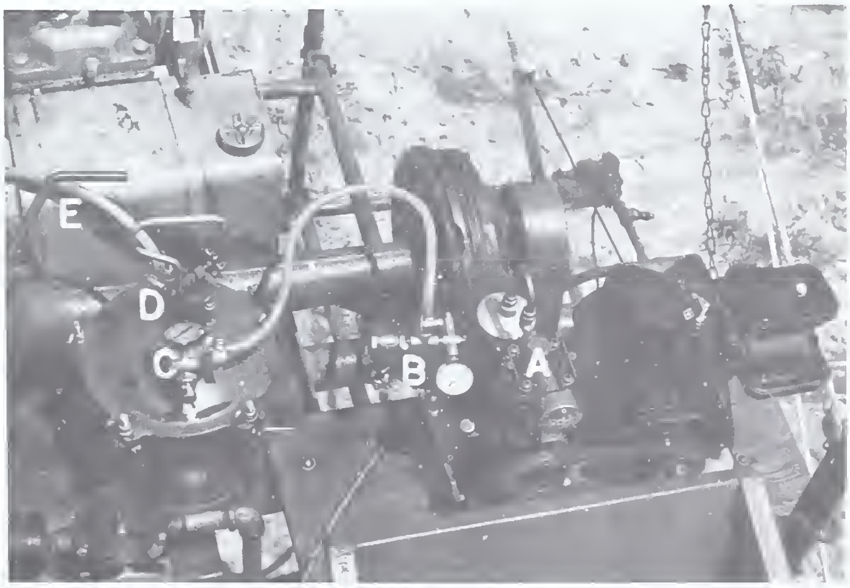

Figure 2.--Pressure unit of sprayer showing portable air compressor (A) with bleeder valve (B); liquid-pressure tank with pressure regulator (C) and liquid flow valve (D). Hose (E) from top of tank goes to nozzles.

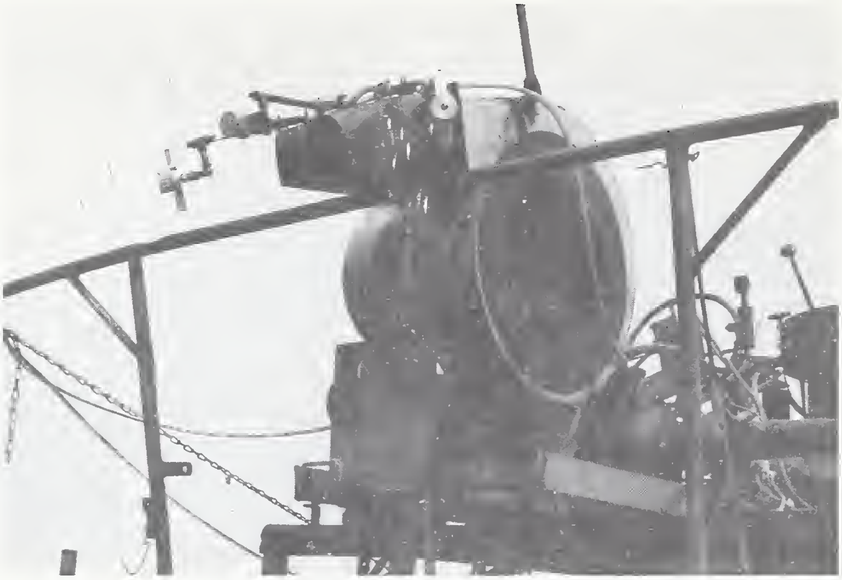

Figure 3.--Low-volume mist sprayer. (Note placement of Mini-Spin nozzle mounted on air outlets of mist blower and sprayer attachment at rear of high-clearance chassis.)

The flow rate of the pesticide is controlled by the size of the orifice in the nozzle metering plate and by the pressure maintained in the pressure tank. With a delivery tube opening from the bottom of the tank, accurately controlled air pressure applied to the liquid eliminated air bubbles in the delivery line, thus a constant flow of liquid to the nozzles is maintained. For ease in handling the different materials tested and for preventing contamination between treatments, all spray materials were placed in individual 3-quart plastic containers in the pressure tank. This procedure eliminated need for thorough cleaning of the tank between treatments. However, before a different treatment was used, the lines and nozzles were cleaned with gasoline, or methyl or isopropyl alcohol.

The Mini-Spin nozzles equipped with 30-mesh screens are placed 9 inches from the outlets of the mist blower. At this distance, the circular air-blasts were of about the same diameter as the nozzle propellers and moved at a velocity of about 110 m.p.h to provide a total air movement of 4,800 cu. ft. per min.

Different sizes of flat orifice metering plates (Spraying Systems Co.) can be used to roughly regulate the rate of flow of the liquid. Final flow rate is regulated by varying the pressure on the liquid in the pressure tank.

The adjustable propeller blades of the nozzles were set at 40° and rotated at speeds varying from 5500 to 7500 r.p.m. The number of revolutions per minute were measured with a photoelectric cell, light source, and oscilloscope.

Part of the atomization of the liquid occurs when the centrifugal force generated by the rotating nozzle flings the liquid out through the rotating atomizer screen. The drops are further atomized when they are struck by the rapidly moving airblast from the mist blower. The spray is then carried down to the plants by airstreams moving at 0.5 to 5.0 m.p.h. when they reach the plants. The spray droplets, interspersed in the large volume of moving air, cover the plants with the insecticide.

In operation the sprayer was driven at 7.7 m.p.h., and plots to be treated were designed for swath widths of 33 feet which covered 10 rows each 40 inches wide. It was later determined that the effective swath width was greater than 33 feet; therefore, some overlap of coverage occurred. However, setting up buffer rows eliminated inter-treatment contamination.

The cost of the components for the experimental spray unit consisting of the mist blower, air compressor, liquid-sprayer tank, Mini-Spin nozzles, valves, hose, pipe, and pipe fittings was less than $1,000. When installed on a self-propelled sprayer chassis, such as the Barrentine, the air compressor could be driven by the power takeoff shaft, which would eliminate need for the small gasoline engine. A simplified liquid-sprayer tank could be substituted for the paint-sprayer tank used on the experimental machine. A simple slow-moving piston pump driven by the power take off from carriage vehicle might be substituted for the compressor and liquid-pressure tank. If the spraying unit were mass-produced, the total cost should not exceed $700 excluding the cost of the carriage vehicle.

MATERIALS AND METHODS

The chemicals evaluated were technical malathion (95 percent); technical Methyl Trithion (95 percent total phosphates); technical microground carbaryl (97.5 percent); carbaryl in No. 70 spray oil (3 lb. per gal.); a combination of technical carbaryl plus No. 70 spray oil, and emulsifiable Indopol polybutene H-100 (3 lb. per gal.) (87 percent carbaryl plus oil and 13 percent Indopol polybutene by volume, respectively), and malathion-TDE solution (4 lb. of each per gal.).

The materials were applied at the following rates, in fluid ounces per acre: Malathion at 6, 12, and 24, with nozzle orifice plate No. 4916-14 at pressures of 7.5, 15, and 42 p.s.i., respectively; Methyl Trithion at 6, with orifice plate No. 4916-14, at a pressure of 7.5 p.s.i.; malathion plus TDE at 32 with orifice plate No. 4916-18 at a pressure of 40 p.s.i.; malathion plus carbaryl; carbaryl plus spray oil; and carbaryl plus spray oil plus Indopol polybutene at 18, 43, and 43, respectively, with orifice plate No. 4916-78 at pressures of 35, 18, and 20 p.s.i., respectively. The technical malathion plus carbaryl formulation was prepared by suspending carbaryl in malathion in a 2:1 weight per weight ratio.

Swath width, droplet size, and number of droplets per square inch were determined on various dates during the season by placing glass microscope slides treated with an oleophobic material, Dri-film SC-87 (General Electric Co.), and held in position in a wire frame centered in the middles between every other row of the 10 row plots being treated. Additional slides were placed in the middles of every other row in the first four rows on the windward side and the middles of every other row in the first six rows on the leeward side.

The slides were examined in natural light at 100X with a compound microscope equipped with an ocular micrometer. Each slide was moved across the stage an equal number of times lengthwise until approximately 200 droplets were examined. Only the droplets in the field of vision encompassing 1525μ in diameter were measured and counted. The number of droplets per square inch was determined by counting the number of droplets on two lengthwise passes (0.264 sq. in.) across the slide.

SPRAYER PERFORMANCE

The low-volume mist sprayer provided excellent control of insects, performed well in the field, produced a fine atomized spray that effectively covered the plants in the 10 rows treated to determine the efficiency and calibrations. Sprayer performance data are presented in tables 1 and 2.

The number of droplets per sq. in. across the swath varied considerably (table 1). The data show that the swath width can be increased over that used in the experiments. The data also show that the velocity of any crosswind in the field affected swath width and that greater numbers of droplets were deposited on the foliage on the leeward side of the swath. This result, however, would not be of too much importance during full field treatment.

The percentage of droplets in each size range varied with the material, formulation, and dosage (table 2). Malathion at rates of 6 and 12 fl. oz. per acre permitted the greatest percentage of droplets in the 0 to 10μ range; malathion at 24 fl. oz., technical malathion plus technical carbaryl, malathion plus TDE, and technical Methyl Trithion in the 41 to 100μ range; and carbaryl plus No. 70 spray oil, and carbaryl plus No. 70 spray oil plus Indopol polybutene H-100 in the 101 to 160μ range. However, by mass or volume, technical malathion plus technical carbaryl had the greatest proportion of droplets in the range of 41 to 100μ; while those of malathion plus TDE, malathion at all dosages, carbaryl plus No. 70 spray oil, and carbaryl plus No. 70 spray oil plus Indopol polybutene H-100 were in the range of 101 to 160μ.

Table 1.--Number of droplets per square inch of different insecticides applied at various distances from center of swath by low-volume mist sprayer with temperature, relative humidity, wind speed, and wind direction at time of delivery (treated rows ran east to west).

Formulation of insecticide	Fl. oz. per acre	Number of droplets per square inch at indicated feet from center of swath on--													Temperature (° F.)	Rel. humidity (pct.)	Wind	
		Windward side					Center	Leeward side									M.p.h.	Direction
		33	27	20	13	7		7	13	20	27	33	40	47				
Tech. malathion, 95 pct.	6	61	49	64	49	53	174	133	121	98	68	45	91	76	92	53	2	S
Do	12	--	30	42	53	30	49	23	23	34	8	15	45	23	83	55	4	SE
Do	24	--	0	0	0	15	712	363	227	121	53	30	--	--	84	56	2	SW
Tech. malathion, 95 pct. + tech carbaryl, 97.5 pct.	18	--	8	8	8	23	197	23	27	34	23	8	8	--	83	68	4	SSW
Tech. malathion + tech. TDE (solution 4 lb. per gal. each)	32	--	0	0	8	8	405	83	246	0	68	23	45	8	91	65	3	SW
Tech. Methyl Trithion, 95 pct. total phosphates	6	--	0	0	0	23	245	254	102	15	0	0	--	--	84	56	2	SW
Tech. carbaryl + No. 70 spray oil, 3 lb. per gal., each (suspension)	43	8	0	8	8	8	38	57	87	38	23	30	23	19	90	65	3	SW
Tech. carbaryl + No. 70 spray oil + Indopol polybutene, 3 lb. per gal., each (suspension)	43	--	19	8	8	8	91	83	227	15	19	21	--	--	84	56	2	SW

Table 2.--Percentage of droplets of insecticides in various size ranges applied with the low-volume mist sprayer.

Formulation of insecticide	Fl. oz. per acre	Percentage of droplets in size range (µ)													
		0 to 10		11 to 40		41 to 100		101 to 160		161 to 220		221 to 280		281 to 340	
		By No.	By Mass	By No.	By Mass	By No.	By Mass	By No.	By Mass	By No.	By Mass.	By No.	By Mass	By No.	By Mass
Tech. malathion, 95 pct.	6	69.2	16.0	15.7	13.0	5.6	13.0	8.6	49.7	1.0	8.3	0	0	0	0
Do	12	66.2	9.5	7.2	5.6	13.3	31.5	12.7	50.0	.6	3.3	0	0	0	0
Do	24	3.0	.4	30.8	12.0	36.8	32.5	25.4	44.0	3.0	7.8	1.0	3.4	0	0
Tech. malathion, 95 pct. + tech. carbaryl, 97.5 pct.	18	24.5	2.4	14.6	5.5	37.0	45.9	21.9	40.2	2.1	6.0	0	0	0	0
Tech. malathion + tech. TDE (solution) 4 lb. per gal. each	32	7.3	.4	46.3	26.0	40.0	55.9	6.3	17.8	0	0	0	0	0	0
Tech. Methyl Trithion 95 pct. total phosphates	6	4.0	.4	26.5	10.4	45.5	49.4	23.5	38.6	.5	1.2	0	0	0	0
Tech. carbaryl + No. 70 spray oil, 3 lb. per gal. each (suspension)	43	8.1	.4	7.0	1.0	22.7	13.8	34.9	37.3	19.8	30.9	6.4	13.2	1.2	3.2
Tech. carbaryl + No. 70 spray oil + Indopol polybutene H-100, 3 lb. per gal. each (suspension)	43	3.1	.2	4.1	1.0	28.0	18.0	43.0	45.8	17.1	25.5	4.1	8.3	.5	1.3

FIELD TESTS IN SMALL CAGES AGAINST THE BOLL WEEVIL AND BOLLWORM SPECIES

The technical materials, as solutions or suspensions were applied to the 10-row treatment plots with the low-volume mist sprayer. Azinphosmethyl plus azinphosethyl plus DDT was applied in 5 gal. of water per acre at 75 p.s.i. with a Barrentine high-clearance, 8-row boom sprayer having Spraying Systems X6 nozzles spaced every 20 inches on the boom.

Boll Weevils

Boll weevils (Anthonomus grandis Boheman) were confined on the terminal growth of treated plants in half-pint screened cages placed in the fourth row of the 10-row treated swath. Cotton squares from treated plants were supplied daily as additional food. The weevils were reared from infested squares and were fed on fresh squares from 2 to 4 days before being exposed. For each treatment 10 replicates of 5 weevils each were caged on the treated plants 1 hour after application of materials (table 3) to determine initial activity of the compounds. Residual activity of the materials was determined by exposing other weevils 24, 48, and 72 hours after the application. Mortality of the weevils was determined after 24 and 48 hours of exposure to the applied materials.

All of the materials were initially effective against the boll weevil. Technical malathion (12 fl. oz., 1 lb. per acre), malathion + TDE solution (32 fl. oz. containing 1 lb. per acre of each material), and technical malathion + technical carbaryl suspension (18 fl. oz. containing 1 + 0.5 lb. per acre of each material, respectively), were the most effective residually.

Bollworms

From 25 to 30 bollworm larvae per treatment were confined singly on the terminal foliage of treated plants in half-pint screened cages on the fourth row of the 10-row treated swath with cotton squares from treated plants supplied daily as additional food. The larvae were collected from untreated cotton and held on squares 1 to 4 days before being used. About equal numbers of second-, third-, and fourth-instar larvae were confined on treated foliage 1 hour after materials were applied and the resulting mortality determined after 24, 48, 72, and 96 hours of exposure. After mortality was determined, the cages were moved daily to new foliage and food (table 4).

The data in test No. 1 indicated that the malathion + TDE solution (32 fl. oz., 1+1 lb. per acre), carbaryl + oil (43 fl. oz., 1 lb. per acre), carbaryl + oil + Indopol polybutene and a suspension of technical malathion + technical carbaryl (18 fl. oz., 1 + 0.5 lb. per acre) were effective against bollworms when applied in low volume.

Table 3.--Initial and residual effectiveness of various technical materials, solutions, and suspensions applied with the low-volume mist sprayer for the control of square-reared boll weevils in field tests with small cages; 10 replicates of 5 weevils per treatment.

Formulation of insecticide	Fl. oz. per acre	Average percent mortality of weevils after indicated hours:							
		Initial test		24-hr. residue		48-hr. residue		72-hr. residue	
		Applied: 8/4 Temp. range: 69°-91° F. Rainfall: 0		Exposed: 8/5 Temp. range: 68°-91° F. Rainfall: 0		Exposed: 8/6 Temp. range: 68°-88° F. Rainfall: 0		Exposed: 8/7 Temp. range: 69°-89° F. Rainfall: 8/8 0.5 in., 102 hrs. after application	
		24	48	24	48	24	48	24	48
Tech. malathion, 95 pct.	12	93	98	88	96	51	75	31	70
Tech. Methyl Trithion, 95 pct.	6	90	98	64	76	66	82	16	38
Tech. malathion + tech. TDE (solution) 4 lb. per gal. each	32	100	100	98	100	98	100	87	100
Tech. carbaryl + No. 70 spray oil (3 lb. per gal.)	43	98	100	50	92	29	63	30	61
Tech. carbaryl + No. 70 spray oil, 87 pct. + Indopol polybutene, 13 pct. (3 lb. per gal.)	43	91	100	36	71	21	57	18	49
Tech. malathion + tech. carbaryl (suspension 2:1 w/w)	18	98	100	92	100	96	100	88	96
Azinphosmethyl-azinphosethyl + DDT (treated control)(1/) 0.25+1.0 lb. per acre	--	84	98	96	100	73	89	62	83
Untreated Control	--	16	30	2	12	0	19	13	41

1/ Conventionally applied in 5 gallons of water per acre.

Table 4.--The effectiveness of various technical materials as solutions or suspensions, applied from the ground with equipment for the control of bollworm species. Individual field tests in small cages. Florence, S.C. 1965.

Formulation of insecticide	Fl. oz. per acre applied	Accumulated percent mortality at indicated hours:			
		24	48	72	96
Test No. 1[1] (Material applied: 8/9; insects exposed: 8/9; temp. range: 68°-89° F.; rainfall: 0)					
Tech. malathion (95 pct.)	12	8	10	10	22
Tech. Methyl Trithion (95 pct.)	6	4	25	44	38
Tech. malathion + tech. TDE soln. 4 lb. per gal. each	32	28	50	74	79
Tech. carbaryl + No. 70 spray oil + Indopol polybutene (3 lb. per gal., 87 pct. carbaryl + oil + 13 pct. Indopol polybutene)	43	48	67	70	80
Tech. malathion + tech. carbaryl (suspension 2:1 w/w)	18	24	40	72	78
Azinphosmethyl-azinphosethyl + DDT (treated control)[2]	0.25+1.0 lb.	5	24	53	60
Untreated Control	--	0	8	8	19
Test No. 2[3] (Material applied: 8/18; insects exposed: 8/18; temp. range: 71°-91° F.; rainfall: 8/20, 2.7 in. 52 hrs. after application)					
Tech. carbaryl + No. 70 spray oil	43	50	69	67	80
Tech. carbaryl + No. 70 spray oil + Indopol polybutene (3 lb. per gal.; 87 pct. carbaryl + oil, 13 pct. Indopol polybutene	43	43	63	63	69
Azinphosmethyl-azinphosethyl (treated control)[2]	0.25+1.0 lb.	14	36	36	48
Untreated control	--	7	11	17	17

[1] 25 larvae. Field population used consisted of 74 pct. H. zea and 26 pct. H. virescens.
[2] Conventionally applied in 5 gallons of water per acre.
[3] 30 larvae. Field population used consisted of 87 pct. H. zea and 13 pct. H. virescens.

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DISCUSSION

Of the various materials used in the experiments, only malathion at present is registered with the U.S. Department of Agriculture for use in low-volume spray applications. Although the low-volume mist sprayer was developed for spraying insecticide concentrates from ground equipment to cotton plants, it can probably be adapted for use on other crops. The equipment should not be used for such applications, however, until further experimental evaluation establishes the safety of such uses and the pesticides have suitable registration.

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